Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

THE PALEOZOIC SECTION OF THE TOMAH AND SPARTA QUADRANGLES, WISCONSIN[1]

W. H. TWENHOFEL AND F. T. THWAITES
University of Wisconsin

INTRODUCTION

The Tomah and Sparta quadrangles lie wholly within and on the northeastern edge of the Driftless Area of western Wisconsin. The first-named quadrangle is directly east of the latter. There are 431 square miles in the two areas.

Little geologic work directly relating to the two quadrangles has been published. As parts of the Driftless Area they have received the attention of many of the students who have been concerned with its peculiar problems. Three university theses which directly relate to the whole or parts of the two quadrangles have been written, but none of these has been published.[2] A short paper by W. D. Shipton gives a description of fulgurites[3] found by him near Sparta, and the same author in a second short paper proposed a new formational term for the fine-grained and shaley sandstones which constitute the middle portion of the exposed Cambrian.[4] Other papers which in some degree bear on the geology of the two quadrangles are Ulrich's "Revision of the Paleozoic Systems,"[5] Bassler's "Bibliographic Index of American Ordovician and Silurian Fossils,"[6] in which is given a geologic section for Wisconsin, and one of Walcott's papers, in which is defined the geologic section for western Wisconsin as worked out by Ulrich.[1] The latest published work relating to the areas is an abstract of a paper read before the Geological Society of America at the Albany meeting. This paper describes the rock terraces which are such conspicuous features of the surface.[2]

---

[1] Published by permission of the state geologist of Wisconsin.

[2] R. B. Johns, "The Physiography and Geology of the La Crosse River Valley." Unpublished thesis, University of Wisconsin, 1900. W. D. Shipton, "The Geology of the Sparta Quadrangle." Unpublished thesis, University of Iowa, 1916. W. O. Blanchard, "The Geography of the Tomah-Sparta Quadrangles." Unpublished thesis, University of Wisconsin, 1917.

[3] W. D. Shipton, "A Note on Fulgurites from Sparta," *Proc. Iowa Acad. Sci.*, XXIII (1916), 141.

[4] W. D. Shipton, "A New Stratigraphic Horizon in the Cambrian System of Wisconsin," *ibid.*, pp. 142–45.

[5] E. O. Ulrich, *Bull. Geol. Soc. Amer.*, XXII (1911), Pl. XXVII.

[6] R. S. Bassler, *Bull. 92, United States National Museum*, II (1915), Pl. II.

DESCRIPTION OF THE GEOLOGIC SECTION

Only rocks of sedimentary origin are exposed in the Tomah and Sparta quadrangles (Fig. 1). Of these there are two groups: an older, consisting of poorly cemented sandstones and compact, firm dolomites, both of Paleozoic age; and a younger, made up of unconsolidated materials of very late geologic time. With the latter this article is not concerned. The strata of both groups are in essentially undisturbed position.

The Paleozoic strata belong to the Cambrian and Ordovician systems.[3] The exposed thickness aggregates between 700 and 800 feet, while wells which have been drilled to the base of the sedimentary sequence show the presence of an additional thickness of about 350 feet. These unexposed strata are of Cambrian age.

CHARACTER AND ROCKS OF THE PRE-CAMBRIAN FLOOR

The rocks composing the pre-Cambrian floor beneath the Paleozoic sediments are known from deep wells and from exposures some miles to the north. Drillings from a well in Tomah indicate a gneiss of medium texture, composed of clear and milky quartz, pink feldspar, and white mica. The nearest exposures to the north are at Black River Falls, where the pre-Cambrian rocks consist of granites, gneisses, diorites, schists, and iron formation.

The exposures of the contact between the Paleozoic and pre-Cambrian rocks and the wells in this and adjacent districts which

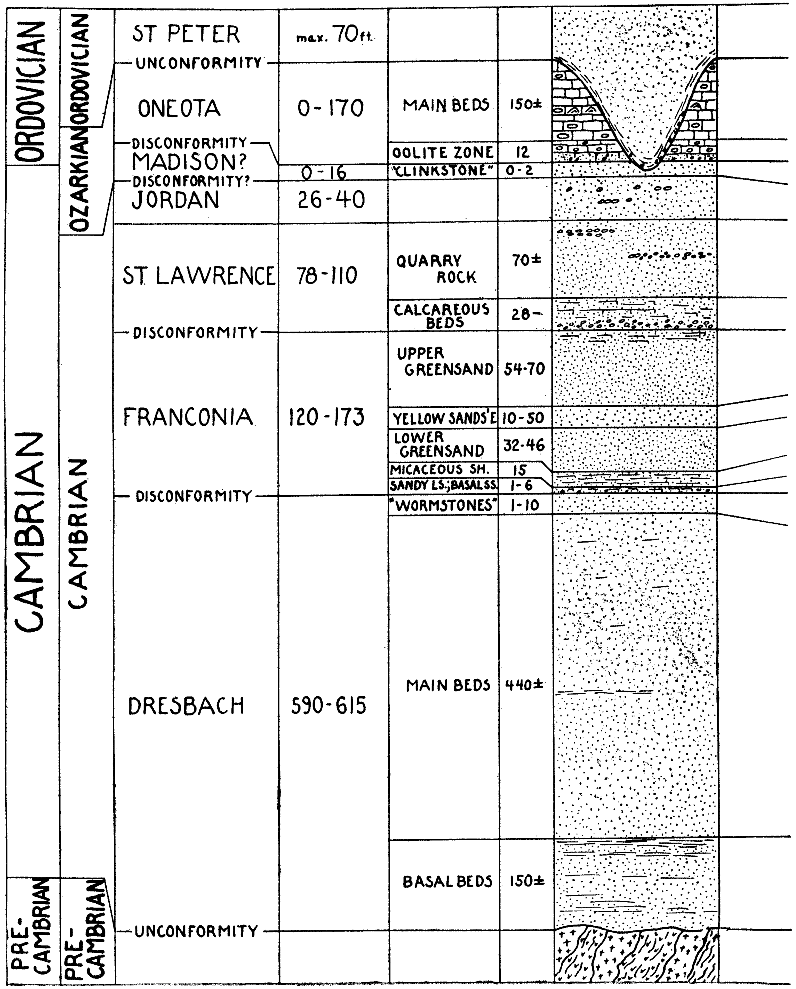
---

[1] C. D. Walcott, "Cambrian Geology and Paleontology," *Smithsonian Misc. Coll.*, LVII, No. 13 (1914), 354.

[2] Lawrence Martin, "Rock Terraces of the Driftless Area of Wisconsin," *Bull. Geol. Soc. Amer.*, XXVIII (1917), 148–49.

[3] If the classification of Dr. E. O. Ulrich be followed, there would be three systems represented: Cambrian, Ozarkian, and Ordovician. Fig. 1 shows the groupings of the systems according to the general usage and also according to the proposals of Dr. Ulrich.

GENERALIZED PALEOZOIC SECTION OF THE TOMAH-SPARTA QUADRANGLES, WISCONSIN



St. Peter. Sandstone, fine- to medium-grained, yellow to brown, locally casehardened, bedding heavy to thin, cross-laminated; at base beds of red and green shale resting on residual clay and chert of Oneota.

Oneota (main). Dolomite, medium-grained, gray to drab, bedding medium to thick, many *Cryptozoa*, rare silicified shells, gray, yellow, and red chert nodules.

Oneota (basal). Dolomite and chert as above, both in part oölitic, beds of sandy dolomite and white and yellow medium- and fine-grained dolomitic sandstone with sandstone and dolomitic pebbles and fragments of green shale.

Madison (?). Sandstone, medium- to coarse-grained, yellow to white, heavy-bedded, quartzite at top (the "clinkstone").

Jordan. Sandstone, coarse- to medium-grained, yellow to gray, heavy-bedded, cross-laminated and cross-bedded, scattered sandstone pebbles; not clearly separated from underlying formation.

St. Lawrence (quarry rock). Sandstone, fine-grained, yellow to white, thin-laminated to heavy-bedded, cross-laminated, mud cracks near base and middle, several conglomerate beds with sandstone pebbles, in part edgewise conglomerate, worm holes and fossil impressions abundant in some layers.

St. Lawrence (calc. beds). Sandstone, very fine-grained to shaley, yellow to light brown, very dolomitic in some beds, local thin beds of gray and purple mottled dolomite, fossiliferous; greensand conglomerate at base.

Upper greensand. Sandstone, fine-grained, light yellow to green, thin to medium bedding, cross-laminated, yellow layers very calcareous, some layers very glauconitic, sparingly fossiliferous.

Yellow sandstone. Sandstone, fine-grained, yellow to gray, heavy-bedded.

Lower greensand. Sandstone, fine-grained, gray to green, thin- to thick-bedded, mud-cracked, highly cross-laminated, with short fore-sets, current and wave ripple-marked, glauconitic, fossiliferous.

Micaceous shale. Fine-grained shaley sandstone, micaceous, thin-bedded, light yellow.

Basal beds. Sandy limestone, pink to brown, glauconitic, fossiliferous; sandstone, coarse- to medium-grained, rough-bedded, conglomeratic with sandstone pebbles, cross-laminated.

"Wormstones." Sandstone, coarse- to medium-grained, gray to brown, beds about 1 foot thick composed of firm sandstone, in which are large vertical worm holes ("wormstones") alternating with thinner beds of soft white sandstone with limonite and siliceous concretions (nodular layers).

Main beds. Sandstone, medium- to coarse-grained, light yellow to gray, bedding medium to heavy, wave and current ripple marks, rare mud cracks, cross-laminated, thin laminae of green shale, possibly a local shale bed a few feet thick about 250 feet below top, local limonite cemented beds. Lower 150 feet known only in wells.

Basal beds. Sandstone as above with beds of red, green, and black sandy shale, shale beds of variable thickness up to perhaps half a dozen feet. Known only in wells.

Pre-C. Granite, gneiss, etc. Known only in wells.

FIG. 1

have been drilled to this contact suggest that the pre-Cambrian lands had been reduced to slight relief before the deposition of the Cambrian sands.

THE CAMBRIAN SYSTEM

Sandstones compose nearly the whole of the Cambrian rocks of the two quadrangles. Some of the finer-grained sandstones have been called shales, but were most of such in association with true shales they quite certainly would be called sandstones. True clay shales are present only as thin laminae and lenses. Dolomite and dolomitic sandstones of local and horizontal distribution also occur. The basal strata of those exposed consist almost wholly of quartz sandstones. The sands are commonly clean and well sorted. The higher Cambrian strata are also largely composed of quartz sands, but some portions contain an abundance of greensand. The top of the Cambrian is quite sharply defined from the base of the Ordovician by the rather general occurrence near the contact of quartzite-like gray sandstones and by the great differences between the dolomite of the basal Ordovician and the sandstone of the highest member of the Cambrian.

Four Cambrian formations are exposed. These, in ascending order, are (1) the Dresbach sandstones, (2) the Franconia glauconitic and shaley sandstones, (3) the St. Lawrence sandstones and dolomitic shales with occasional dolomite layers, and (4) the Jordan sandstones. There is a possibility that a fifth Cambrian formation is present, since at the top of the Cambrian sequence there are a few feet of strata which somewhat resemble the Madison sandstone. The 350 feet of unexposed strata may contain the Eau Claire and Mount Simon formations of Dr. Ulrich's section. The total thickness of the Cambrian is about 900 feet (Fig. 2).

The Cambrian sediments were deposited in shallow water above wave-base. This is proved by the abundant occurrence of both wave and current ripple mark and the wonderful development of cross-lamination in which there are steep fore-sets up to 50 feet in length. Mud cracks, which are present in at least three horizons, prove that at times the sediments were exposed to the drying effects of the sun. The rounding, sorting, and cross-lamination of some of the sands suggest local eolian deposition.

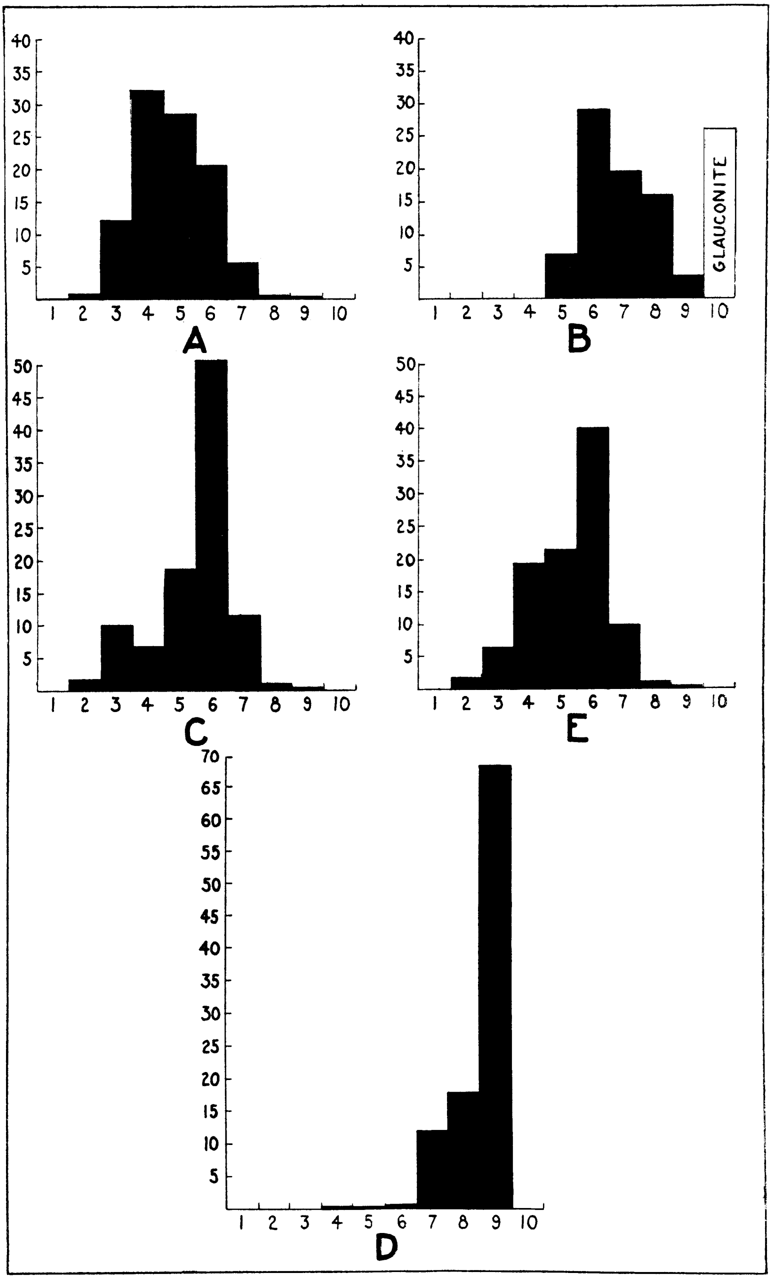


FIG. 2.—Mechanical analyses of characteristic sands (for description see opposite page).

EXPLANATION OF THE DIAGRAMS OF FIG. 2

The ordinates represent percentages by weight, the sum of all the rectangles in each diagram totaling 100 per cent. Abscissae represent the dimensions of the quantity indicated by the rectangle immediately above it. These for convenience are numbered 1 to 10, the dimensions corresponding to the numbers being as given below. The analyses were made with Tyler Standard Screen Scale Testing sieves:

1. Between 1.168 and .833 mm.
2. Between .833 and .589 mm.
3. Between .589 and .417 mm.
4. Between .417 and .295 mm.
5. Between .295 and .208 mm.
6. Between .208 and .147 mm.
7. Between .147 and .104 mm.
8. Between .104 and .074 mm.
9. Smaller than .074 mm.
10. This does not represent dimensions, but material which is different from the main body of the sand. The loss in sifting (generally less than 1 per cent) has been added to No. 9, as the finest grades suffer the greatest loss.

A. Dresbach sandstone, Tunnel City, 65 feet from the top of formation.

Percentage

1. 0.036, spherical grains of transparent quartz.
2. 0.755, well-rounded grains of transparent quartz.
3. 12.080, transparent quartz, most grains well rounded, a few subangular.
4. 32.120, transparent quartz, grains well rounded to subangular.
5. 28.270, transparent quartz, grains well rounded to subangular, a few grains angular.
6. 20.460, transparent quartz, estimated 10 per cent angular, 25 per cent well rounded.
7. 5.600, transparent quartz, a few grains well rounded, most subangular to angular.
8. 0.312, transparent quartz, nearly all grains sharply angular.
9. 0.367, transparent quartz, grains angular.

This sand is of beach origin.

B. Lower greensand of the Franconia formation, collected at Boscobel on the Wisconsin River, south of the quadrangles.

Percentage

1. 0.00.
2. 0.00.
3. 0.00.
4. 0.00.

	Percentage	
5.	6.83,	transparent quartz, grains subangular to angular.
6.	28.80,	essentially no rounding.
7.	19.27,	no rounding, a little dolomite.
8.	15.71,	as No. 7.
9.	3.47,	as No. 7, with about 10 per cent dolomite.
10.	25.84,	this rectangle represents the glauconite present in the sample.

This sand was deposited some distance from the belt of constant wave-wash as shown by its fineness and little rounding.

C. Fine-grained sandstone from near base of the Jordan, Jeff Davis Rock, Tomah quadrangle.

	Percentage	
1.	0.00.	
2.	1.78,	transparent quartz, grains highly spherical and pitted.
3.	10.00,	transparent quartz, high sphericity, grains pitted.
4.	6.45,	transparent quartz, high sphericity, grains pitted, estimated 5 per cent subangular.
5.	18.52,	transparent quartz, with a few grains of limonite, grains well rounded and pitted, 5 per cent subangular.
6.	50.50,	as No. 5.
7.	11.29,	transparent quartz, well rounded with a few angular grains.
8.	1.06,	transparent quartz, 60 per cent subangular to angular.
9.	0.40,	transparent quartz, with a little clay, and dolomite, about 5 per cent rounded, about 10 per cent aggregates of finely divided quartz.

The assortment, rounding, and cross-lamination of this sand suggest wind deposition.

D. St. Lawrence sandstone, 2 miles southeast of Norwalk, Wis., 50 feet below base of Oneota. Contains marine fossils.

	Percentage	
1.	0.00.	
2.	0.00.	
3.	0.00.	
4.	0.40,	transparent quartz, grains rounded.
5.	0.36,	transparent quartz, rounded and subangular grains, estimated 10 per cent muscovite flakes.
6.	0.60,	as No. 5.
7.	12.00,	transparent quartz, angular grains, occasional muscovite flakes and limonite grains, a little dolomite.
8.	17.92,	transparent quartz, nearly all grains angular.
9.	68.72,	transparent quartz, 75 per cent aggregates, no rounding whatever.

The last rectangle does not express the actual facts as it is composed of grains varying from .074 mm. in diameter to dimensions fully one one-hundredth of that dimension. This sand was deposited beyond the zone of constant wave-wash.

E. St. Peter sandstone, Cashton, on the southwestern edge of the Sparta quadrangle, estimated 30 feet above the base.

	Percentage	
1.	0.00.	
2.	1.80,	transparent quartz, high sphericity.
3.	6.28,	as No. 2.
4.	19.21,	as No. 3.
5.	21.42,	transparent quartz with a few limonite grains and fragments of calcite, most well rounded, but numerous subangular grains.
6.	40.00,	transparent quartz with a few grains of limonite, well rounded, estimated 25 per cent subangular.
7.	9.81,	as No. 6, 50–60 per cent subangular, 10 per cent angular with no rounding.
8.	1.13,	transparent quartz, 75 per cent sharply angular, rest subangular.
9.	0.352,	transparent quartz, with rare garnet grains, essentially all angular.

The assortment, rounding, and cross-lamination of this sand suggest wind deposition.

Save for local and horizonal exceptions, the Cambrian sandstones are poorly cemented. Most of the beds crumble on slight exposure and in numerous places fresh rock may be crushed to sand with the hands.

THE DRESBACH FORMATION

The type locality for the Dresbach formation, first called the "Dresbach sand rock," is at Dresbach, Winona County, Minnesota, 18 miles west of this area. At Dresbach the character and sequence of the strata appear to be quite similar to what they are in these quadrangles, although lower shaley strata are present there which have not been differentiated in this area.[1] What is known of the unexposed Cambrian strata of these two quadrangles is included in the description of the Dresbach formation, although it is quite possible that these strata contain the Eau Claire and Mount Simon formations.

The Dresbach strata immediately underlie the lower lands of the two quadrangles. Where the formation has been completely uncovered through the removal of the higher formations, there has developed a gently rounded, discontinuously terraced topography. Along the deeper valleys, in such places where the overlying formation has not been completely removed, the upper strata of the Dresbach rise from steep slopes to form coalescing tower-like cliffs or conical buttes.

---

[1] N. H. Winchell, *Minn. Geol. and Nat. Hist. Surv., Final Rept.*, II (1888), xxi.

Characteristics.—The exposed strata of the Dresbach consist of poorly cemented quartz sandstones of which the grains are clean and well rounded. In most of the beds the assortment is extremely good. Interlaminated with the exposed sandstones are thin lenses (up to about a centimeter in thickness) of green sandy shale. Well records show the presence in the unexposed strata of greenish, bluish, and reddish shale. Most of these occur about 450 feet below the top of the Dresbach and may represent a part of the Eau Claire formation. The sands are generally poorly cemented, and very few layers are sufficiently firm for use in construction. The colors vary from gray to yellow. "Iron rocks"—sands cemented by hydrous iron oxide—are locally present in considerable abundance, but are not characteristic of any horizon.

The strata are not continuous for long distances, and with the exception of worm-perforated beds, which are prominent in the upper horizons, it has not been found possible to identify any portion beyond the limits of a single exposure. In the field these upper strata were known as the "wormstones." Cross-lamination at variable inclinations with variable directions is present in nearly every outcrop. The fore-sets are generally short, 5 to 6 feet being the average maximum, but in an outlier near the village of Rockland there are fore-sets at angles of 15° to 20° which exceed 50 feet in length. The inclination of the long fore-set cross-lamination at Rockland is nearly due east. In a number of cases the cross-lamination has the appearance of having been produced by wind deposition. The nature of the Dresbach sediments was not favorable for the development of mud cracks, but such are present just east of Rockland in a horizon about 100 feet below the top of the formation.

The thickness of the exposed Dresbach is about 300 feet. Well records show that from 590 to 615 feet are present from the base of the Franconia formation to the pre-Cambrian floor.

Except for worm tubes, of which there appear to be at least two varieties, fossils have not been observed in the Dresbach sandstones of the two quadrangles. The most common worm tubes are of the Scolithus type. They are extremely abundant in the upper beds.

Conditions of origin.—The sediments of the Dresbach formation were accumulated in shallow water above wave-base or above water-level. It does not seem probable that at any time the waters attained sufficient depth to remove the sands from the wash of the waves. The possible eolian cross-lamination and certainly the mud cracks prove that at times the sites of deposition were above water-level. The writers' conception of the conditions of deposition is that of an extensive sand flat, of which parts may have been continuously underneath the water, other parts were exposed at low tide, while other areas—sand islands, bars, etc., thrown up by the waves and piled higher by the winds, the different environments shifting more or less from time to time—were above water-level. These conditions granted, the clean washing of the sands, the local thin laminae of shale, the presence of mud cracking, the abundance of both wave and current ripple mark, the excellent sorting of the sands in most of the beds and their quite perfect rounding in some beds, the great development of cross-lamination of which some appears to be eolian, the variable and lenticular character of Dresbach bedding, and the general absence of fossils follow as natural consequences, and it is difficult to conceive how all these characters could have developed on an extensive scale under any other conditions.

THE FRANCONIA FORMATION

The Franconia formation was defined by Berkey[1] without its upper and lower limits being stated. In some of the publications of the United States Geological Survey the strata which constitute the Franconia formation appear to have been included in the St. Lawrence,[2] which as thus defined includes two stratigraphic units of decidedly different lithology which are separated by a quite generally well-exposed greensand conglomerate. The strata, which in this article are referred to the Franconia formation, are included between the top of the Dresbach and the base of this greensand conglomerate.

---

[1] C. P. Berkey, "Geology of the St. Croix Dalles," *Amer. Geol.*, XX (1897), 373, 377.

[2] G. W. Hall, O. E. Meinzer, and M. L. Fuller, "Geology and Underground Waters of Southern Minnesota," *Water Supply Paper No. 256, U.S. Geol. Surv.* (1911), pp. 63–68; W. H. Morton and others, "Underground Water Resources of Iowa," *Water Supply Paper No. 293* (1912), Pl. II, p. 65.

The Franconia strata cap divides over considerable portions of the northern halves of the two quadrangles. These have a rolling, more or less terraced, topography with mammillary knolls. Where overlain by higher strata the Franconia makes a terraced slope on which at least two terraces are almost everywhere present.

Relations to the Dresbach formation.—There is apparent conformity between the Franconia and Dresbach formations; but the fact that there are some differences in the sequence at the top of the Dresbach and the presence at the top of that formation of what may be small erosion channels suggest that the contact of the two formations is one of disconformity, with the possibility that the lower was eroded before the deposition of the upper.

Subdivisions and their characteristics.—The greater portion of the Franconia formation consists of fine-grained quartz and glauconitic sandstones. The clay content is limited to thin shale partings. A few beds contain small percentages of dolomite and near the base there is a sandy limestone. There are few beds in the formation which do not contain some greensand.

The thickness of the Franconia varies from 120 to 173 feet. The thickest sections are in the northern halves of the two quadrangles, although a well drilled at Cashton, just off the southeast corner of the Sparta quadrangle, indicates a thickness of about 170 feet. The thinnest section, 120 feet, was measured near the center of the Sparta quadrangle.

It is possible to divide the Franconia formation into five members, which in ascending sequence are: (1) the basal sandstone and overlying calcareous layer, (2) the micaceous shale, (3) the lower greensand, (4) the yellow sandstone, and (5) the upper greensand. These five members are continuous over the whole of the two quadrangles and for considerable distances beyond their limits.

1. The basal sandstone is roughly and irregularly bedded and is everywhere cross-laminated. Colors vary from gray to brown with

some layers so rich in greensand as to have a greenish-black color. Sorting is extremely poor. Fossil fragments, of which every one appears to have been washed about for a considerable time before final deposition, are locally very abundant. The thickness varies from 1 to 6 feet.

The overlying calcareous layer varies from a calcareous sandstone to a nearly pure limestone. The rock has a brownish-pink to red color and is generally cross-laminated with short fore-sets to the laminations. These have no constant direction of inclination. Small articulate brachiopods are present locally in considerable abundance. The thickness varies from nothing to about 4 feet.

2. The micaceous shale is really a fine-grained, thin, laminated sandstone. The colors vary from gray to yellow. The sandstone is composed chiefly of quartz with some of the bedding and lamination planes containing an abundance of thin flakes of white and colorless mica. Some beds are current-ripple marked and others have the bedding planes abundantly covered with fucoidal markings. Fossils, all of which appear to have been washed about before deposition, are quite abundant. The thickness varies around 15 feet.

3. The lower greensand is composed of thin laminated glauconitic and quartz sandstones. Greensand is present in essentially every bed; the proportion varies widely. Some thin layers are fully 75 per cent greensand, many beds have more than 20 per cent, while in others its occurrence is limited to occasional grains. Some of the strata are evenly bedded, but more commonly the bedding is decidedly irregular and lenticular. Cross-lamination is present throughout. The fore-sets are generally short and apparently have no uniform direction of inclination. Near the middle are mud-cracked layers which have been seen in nearly every exposure of the member. Both wave and current ripple mark, the latter by far the more abundant, are present in every exposure of any size. Fossils, all of which appear to have been washed about before final deposition, are common in many beds. The thickness varies around 40 feet.

4. The yellow sandstone member is composed of thick-bedded, horizontal and cross-laminated yellow and gray sandstone. Greensand is present in some layers. Transverse worm tubes are the

only fossils which have been seen. The thickness varies from 40 to 50 feet.

5. The upper greensand is similar in its characteristics to the lower greensand, but fossils are not nearly so common. Near the top are thin layers (1 inch maximum thickness) of very dolomitic, fine-grained, yellow sandstone interbedded with highly glauconitic medium-grained sandstone. Iron pyrite has been observed locally. The thickness varies from 54 to 70 feet.

Conditions of origin.—The Franconia sediments are wholly of marine origin, a conclusion proved by the quite general abundance of marine fossils. The cross-lamination everywhere present shows that the deposition took place above wave-base. The much smaller dimensions of the grains of sand and the higher percentages of angular grains suggest that the waters were considerably deeper than were those in which the Dresbach sediments of these quadrangles were deposited. The mud cracks in the lower greensand prove that at times during the deposition of that member several hundred square miles of the two quadrangles lay above water-level. The writers believe that somewhat similar shore conditions obtained during Franconia time as during Dresbach, with the difference that the Franconia sediments were deposited somewhat farther from land influences. Any interpretation must take into consideration the occurrence and abundance of greensand. This evidence has not been thoroughly evaluated, but nothing has been discovered which is not in harmony with the foregoing interpretation.

THE ST. LAWRENCE FORMATION

The St. Lawrence formation was defined by N. H. Winchell as the St. Lawrence limestone.[1] Its limitations were not definitely given because they were not known. The stratigraphic boundaries as they exist in western Wisconsin were worked out by Ulrich, and in this article the term is used with the significance given it by him. The strata of the two quadrangles which are referred to the St. Lawrence by the writers were designated the Sparta shales by Shipton on the supposition that they represented an undescribed stratigraphic unit.[1] This supposition does not appear to be correct.

---

[1] N. H. Winchell, *Minn. Geol. and Nat. Hist. Surv., Second Ann. Rept.* (1874), pp. 152–55; *Fourth Ann. Rept.* (1876), pp. 32–34.

Where the St. Lawrence is not overlain by higher strata there develops a rolling topography of gentle outlines. Where higher strata are present there is a gently sloping surface on which relatively resistant strata near the middle of the formation give rise to discontinuous terraces. Quite commonly the upper beds of the St. Lawrence form the basal portions of the higher tier of cliffs.

Relations to the Franconia formation.—At all places where the contact between the Franconia and the St. Lawrence has been seen there is present an edgewise conglomerate composed of pebbles derived from the upper greensand member of the Franconia. These pebbles appear to have been indurated before their deposition, thus indicating the exposure and erosion of Franconia rocks at the beginning of the St. Lawrence deposition. If such erosion has occurred, as appears quite probable, it follows that the two formations are separated by a disconformity. The variation in thickness of the Franconia is in harmony with this conclusion.

Characteristics.—In the exposures of the Tomah and Sparta quadrangles the St. Lawrence formation consists largely of sandstones. Some of the beds of the lower half are more or less dolomitic and shaley and others contain small quantities of greensand. Farther to the southeast in the Wisconsin Valley the dolomite content is greater, and one member of the formation is a dolomite.

It is possible to divide the St. Lawrence into two members: a lower, composed of shaley and fine-grained, light-yellow to light-brown sandstone in which there are some dolomitic layers with local lenses (1 foot maximum thickness) of gray- and purple-spotted dolomite and also a little greensand, and an upper, consisting of fine-grained yellow sandstones in which are several layers (6 inches to 4 feet) of conglomerate composed of fine-grained yellow sandstone pebbles of lenticular shapes in a matrix of yellow sandstone of coarser grain. The pebbles are commonly in horizontal position, but a conglomerate near the middle of the formation has them in edgewise position with inclinations varying to nearly vertical. The sandstones are generally thin-laminated and quite regularly bedded. In some of the layers, particularly those in the upper member, cross-lamination is present to a high degree. The angles of inclination are generally low and of variable direction; but inclinations of southerly direction appear to be the more common. The thickness varies from 78 to 110 feet.

---

[1] W. D. Shipton, "A New Stratigraphic Horizon in the Cambrian System of Wisconsin," *Proc. Iowa Acad. Sci.*, XXIII (1916), 142–45.

Fossils are extremely abundant in some layers, most of them being trilobites. One of the locally developed dolomitic layers of the lower member contains numerous brachiopods which are identical with, or closely related to, *Billingsella coloradoensis* (Shumard). The broken condition of the trilobites indicates that they were washed about by waves and currents before their final deposition.

Conditions of origin.—The St. Lawrence strata are of marine origin, and the sediments composing them were deposited in shallow water. Some beds were deposited under conditions which permitted the development of mud cracks, such having been found near the base of the formation on the northeastern edge of the Tomah quadrangle and near the middle of the lower member on the Wisconsin River. The numerous bands of conglomerate prove waters sufficiently shallow for the transportation of good-sized pebbles over extensive areas; presumably these were derived from the shores and carried out to deeper waters. They may possibly indicate backward and forward migration of the shore line. It is believed that the broad sand-flat conditions postulated for the times of the preceding formations were still existent, and that the St. Lawrence sediments indicate somewhat greater depths of water and greater distances from land conditions than obtained during the deposition of the Dresbach sediments of the two quadrangles.

THE JORDAN FORMATION

Succeeding the fine-grained sandstones of the upper St. Lawrence are sandstones which are correlated with the Jordan formation of Minnesota, the writers using that term in the sense defined by Ulrich in the paper by Walcott. Throughout the two quadrangles the sandstones referred to this formation in large part make the upper tier of cliffs.

Relations to the St. Lawrence formation.—In many places it is extremely difficult to locate the surface of division between the St. Lawrence and Jordan formations. Locally the strata assigned to the Jordan begin with a long, fore-set, cross-laminated stratum which in comparison with the more horizontally laminated St. Lawrence makes the contact quite conspicuous. In some exposures a thin layer of conglomerate marks the contact. In their larger relations the two groups of rocks are quite different, the bedding of the Jordan being much more irregular and the sands more coarse than obtain in the St. Lawrence. The writers have observed no decisive evidence in this area that the St. Lawrence strata were eroded before the deposition of the Jordan.

Characteristics.—The Jordan formation in these two quadrangles consists wholly of sandstone. The textures vary from coarse to fine and the colors from gray to light brown. The sorting is generally not good. Some beds contain an abundance of fine-grained sandstone pebbles. A characteristic feature is the presence of calcareous concretions with diameters varying from a fraction of an inch to about 2 inches. The bedding is massive and extremely irregular. Cross-lamination and cross-bedding are present throughout, some of the fore-sets being up to 50 feet in length and having angles of inclination for such lengths up to 25°. Directions vary, but the writers' observations indicate a dominance of inclination in a southerly direction. No fossils have been observed in this formation in either of the two quadrangles. The thickness varies from about 20 to about 40 feet.

Conditions of origin.—There is no known evidence in either of the two quadrangles to indicate that the Jordan sandstone is of marine origin. Parts of it appear to have been deposited by the wind. To the writers it appears probable that the formation represents the emergent deposits consequent upon the complete withdrawal of the waters from the sand flats postulated for the times of the preceding formations.

THE MADISON (?) FORMATION

Overlying the sandstones which have been identified as belonging to the Jordan are other sandstones which in some respects resemble those of the Madison formation. These sandstones are better stratified than are those immediately below. They are also usually more or less dolomitic, and at or near the top there is quite generally a hard quartzite-like sandstone to which the field name of "clinkstone" was given. Up to the present these sandstones have yielded no fossils other than worm borings which resemble those found in the typical Madison sandstone. The thickness varies from 2 to about 20 feet.

If these sandstones are really of Madison age it is probable that an erosion interval occurred between the deposition of the Jordan and the Madison. The decisive evidence for such an interval has not been found in these quadrangles, although suggested by the considerable variation in the thickness of the Jordan. Such variation in thickness, however, is readily explained through inequality of deposition, which is a rather usual condition in sandstone deposits. Near Madison the Mendota dolomite is said by Ulrich to hold a stratigraphic position between the Madison and Jordan formations.[1] If this be correct and these sandstones are really of Madison age, there is little doubt of the presence of a disconformity.

ORDOVICIAN SYSTEM

INTRODUCTION

Only two formations of the Ordovician system are present within the two quadrangles. These are the Oneota dolomite (in the arrangement of the systems of Dr. Ulrich the Oneota and the Madison are referred to his Ozarkian system) and the St. Peter sandstone, each markedly different from the other in character, origin, and distribution. The two formations are separated from each other by a decided disconformity of marked relief.

THE ONEOTA FORMATION

The Oneota formation underlies the higher uplands and, except for small outliers, is largely confined to the southern halves of the two quadrangles. These upland areas have gentle outlines and slope with slight inclination in a southwesterly direction.

---

[1] E. O. Ulrich, "Correlations by Displacements of the Strandline, etc.," *Bull. Geol. Soc. Amer.*, XXVII (1916), 460.

The Oneota is quite commonly considered the lower member of the Prairie du Chien formation. In the older nomenclature it constituted one of the members of the Lower Magnesian group.

Relations to underlying strata.—There is essential parallelism between the beds of the Oneota and underlying strata, but it is believed that the latter were eroded before the deposition of the former. The basal bed of the Oneota is quite commonly a conglomerate, and mud cracking is not rare in the associated clayey beds. The quartzite-like beds—the "clinkstones"—in the upper portion of the Madison (?) may be a case of pre-Oneota case-hardening resulting from exposure before Oneota deposition. Near Madison bowlders of a quite similar quartzite are present in the basal Oneota, suggesting that the foregoing is a possibility. The thickness of the underlying sandstones varies from place to place, and the upper surface of these sandstones suggests erosion before the deposition of the Oneota.

Characteristics.—The Oneota formation consists of firm and compact dolomites in regular beds. Colors vary from gray to drab. Some of the lower beds are oölitic. The basal beds are somewhat sandy, and a conglomerate of dolomite and sandstone pebbles in a sandy dolomite matrix is quite commonly present at the base. This conglomerate and some of the immediately overlying sandstone beds contain flakes of green shale. The sandy beds persist through about a dozen feet of strata. Quite commonly the sandy beds are so firmly cemented as to form quartzite. A few feet above the base there is a rather persistent bed of fine-grained white sandstone which locally is firmly cemented to form a white quartzite. Much gray, blue, and yellow chert is present throughout, and some beds contain vast quantities. The chert of the oölitic layers is also oölitic. The dolomite contains many small cavities, some of which are lined with white, yellow, and amethystine quartz.

The maximum thickness of the Oneota in these areas is not believed to exceed 170 feet.

The most common fossils of the Oneota formation are irregular masses of *Cryptozoa*. These are abundantly present as isolated individuals and more rarely as reeflike masses, one of the latter quite commonly being present about 30 feet above the base. In fully half of the occurrences they are composed of chert. Other common fossils are small cephalopods, low-spired gastropods, and shells of a chiton-like organism. These are generally poorly preserved, casts and molds being the only forms which have been observed, and the writers—the chiton-like form excepted—have found them only in the chert. The writers have found no fossils composed of dolomite except those of *Cryptozoa.*

Conditions of origin.—The strata of the Oneota formation are wholly of marine origin. They are not the deposits of deep water, but in large part appear to have been deposited below wave-base.

THE ST. PETER FORMATION

The St. Peter sandstone occurs only as small patches which fill erosion depressions in the Oneota. None has been discovered over the northern half of the area. The most extensive occurrence is in the southeastern corner of the Sparta and the adjacent part of the Tomah quadrangle. Residual float from the St. Peter is quite abundantly present over those parts of the uplands which are underlain by the Oneota.

Relations to underlying formations.—The most striking feature of the St. Peter formation is the relief of the disconformity which marks its base. The stratigraphic position of the St. Peter in this region is above the Shakopee formation; but that formation, if deposited over these two quadrangles, was removed before St. Peter deposition, so that the St. Peter rests on the Oneota, except in one exposure, where it was found to rest on the Jordan, thus giving to the surface of disconformity a stratigraphic relief of fully 200 feet.

Characteristics.—The St. Peter formation consists of loose, friable, yellow to brown, fine- to medium-grained sandstone with a variable thickness of red and green non-calcareous shales and fine-grained shaley yellow sandstones in the basal portions. At every place where the base of the stratified St. Peter was observed it rests on a residuum of red clay and chert which is altogether without stratification. This residuum was derived from the weathering of the Oneota and possibly higher formations. In this article this unstratified material is assigned to the St. Peter, although it developed during the time of erosion which intervened in this area between the Oneota and the St. Peter and thus might be considered a distinct formation. Some of the sandstones are locally so case-hardened as to resemble quartzite, and these form a residual float over the surface of the Oneota. In many cases the sandstones are so little cemented as to be quarried for sand. Except for the basal layers, the sands are clean, well sorted, and well rounded. A large proportion of the grains are of high sphericity. The strata immediately above the residuum are fairly well bedded. Higher strata have all degrees of cross-lamination and cross-bedding.

The known thickness of the St. Peter in this area does not exceed 70 feet. No fossils have been found in the St. Peter sandstones of this area or, for that matter, in any part of Wisconsin known to the writers. In eastern Minnesota the St. Peter has yielded fossils.[1]

Conditions of origin.—While all the facts relating to the origin of the St. Peter have not yet been completely evaluated and more data are being collected, it does not appear probable to the writers that any part of the St. Peter sandstones in either of the two quadrangles is of marine origin. The basal portions are certainly of residual origin and as this residuum extends over the tops of the St. Peter hills it proves the absence of marine-wave wash during the deposition of all material up to the tops of these hills. The shales and sandstones immediately overlying the basal residuum appear to be of stream deposition. The higher, clean, cross-laminated sands have characteristics which suggest their modification and deposition by the wind.

CONCLUSION

With the St. Peter formation the Paleozoic section of the Sparta and Tomah quadrangles is concluded. That other Ordovician and also Silurian formations once extended over this region is strongly suggested, if not proved, by the ragged edges of strata of these two systems which are found at comparatively short distances to the south and west. It is possible that formations younger than the Silurian were once present; but, if so, evidence of their former existence has not been discovered.

---

[1] F. W. Sardeson, *Bull. Minn. Acad. Nat. Sci.*, IV, No. 1 (1896), pp. 64–88.